OCEANOGRAPHY WITH GPS

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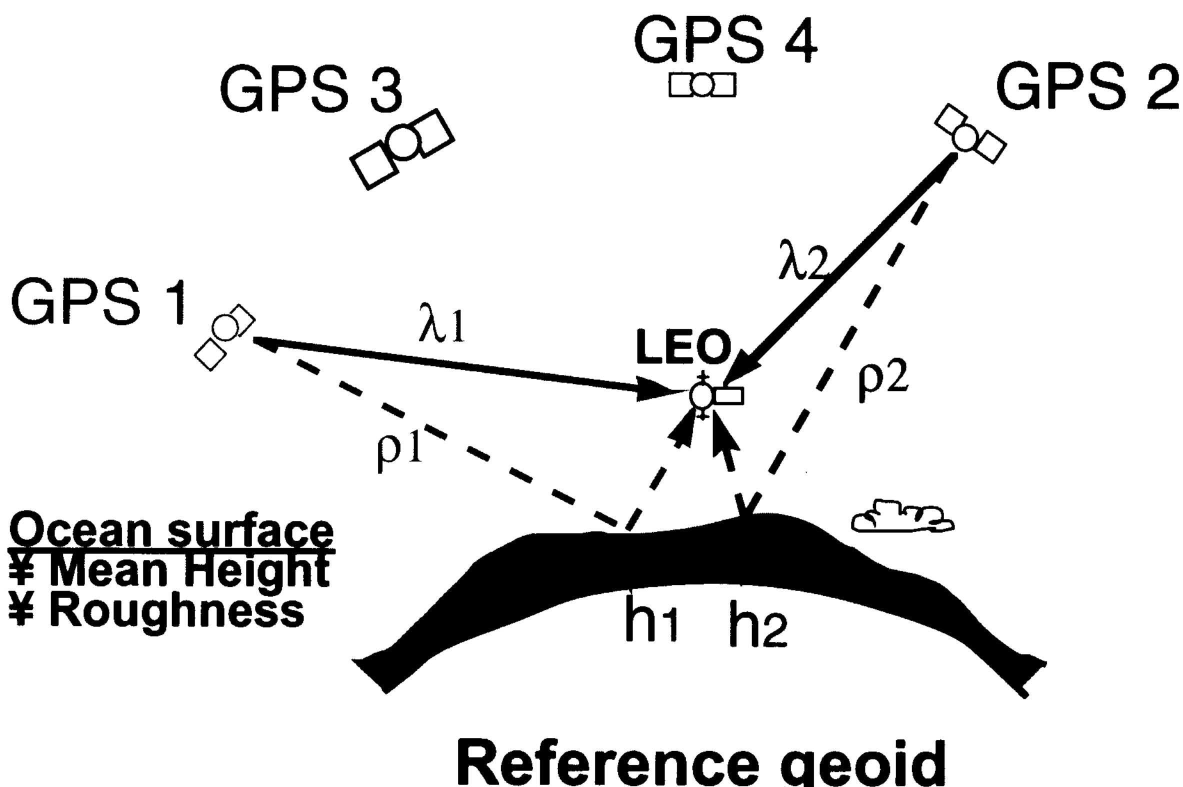
OUTLINE

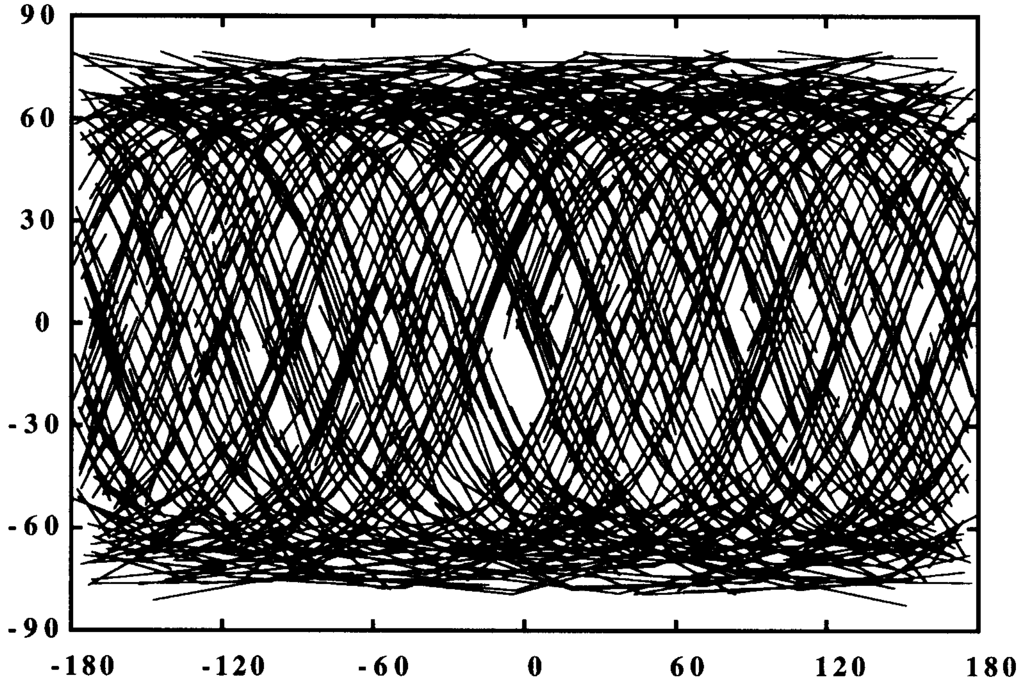
- **SCIENTIFIC MOTIVATION – FAST MOVING WAVES AND MESOSCALE EDDIES**
- **THE GPS ALTIMETRY CONCEPT – TEMPORAL AND SPATIAL COVERAGE**
- **SIGNAL CHARACTERISTICS AND RELATIONSHIP TO SEA STATE PARAMETERS**
- **ANOTHER APPLICATION – COASTAL MONITORING**
- **GPS HERITAGE AND PRELIMINARY RESULTS**
- **SYSTEM LEVEL CONSIDERATIONS FOR A SPACE-BASED DEPLOYMENT**

GPS ALTIMETRY CONCEPT



TIME (PATH) DIFFERENCE $\rho_i - \lambda_i$ MAPS INTO SURFACE HEIGHT

EARTH DAILY COVERAGE FROM SINGLE SPACE-BASED GPS RECEIVER



ON AVERAGE, 12 4-SEC-MEASUREMENTS PER 50 km x 50 km CELL IN TEN DAYS

POTENTIALS

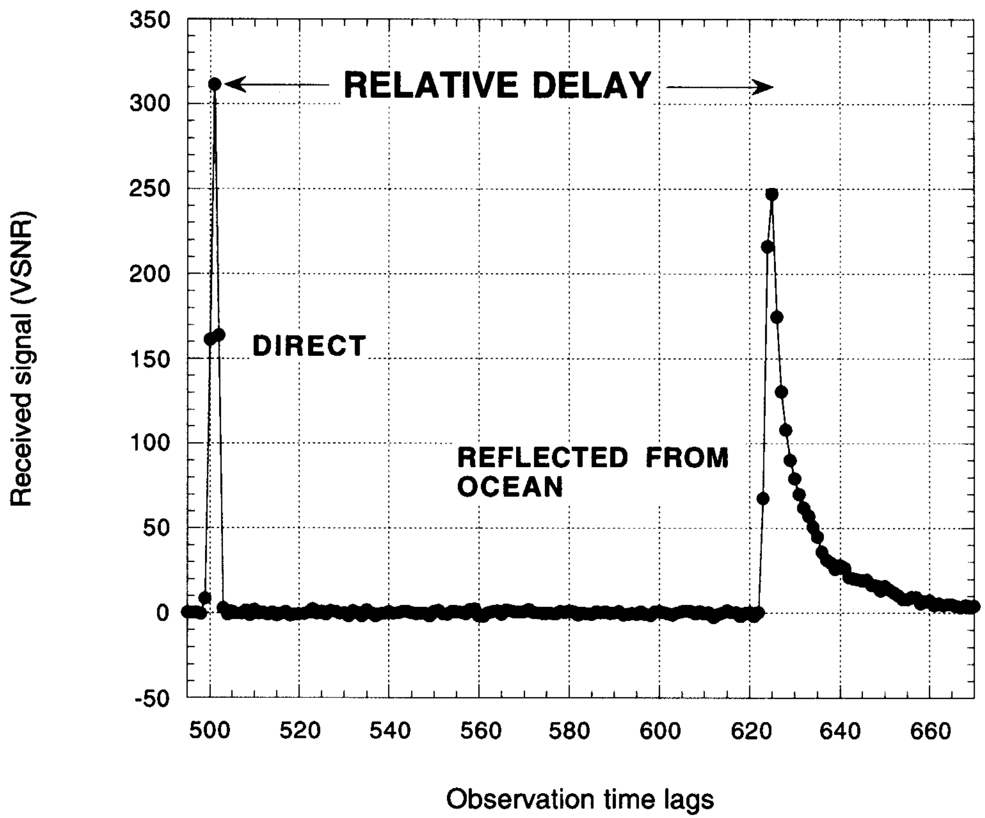
GPS Could Provide An <u>AUGMENTATION</u> To Existing Altimetry From Space, Since The <u>GPS COVERAGE IS DENSE AND RAPID</u>. In Fact:

- **Many Measurements Can Be Obtained, Providing Global Sea Surface Mapping In Times Shorter Than The Traditional Altimeters Repeat Cycles**

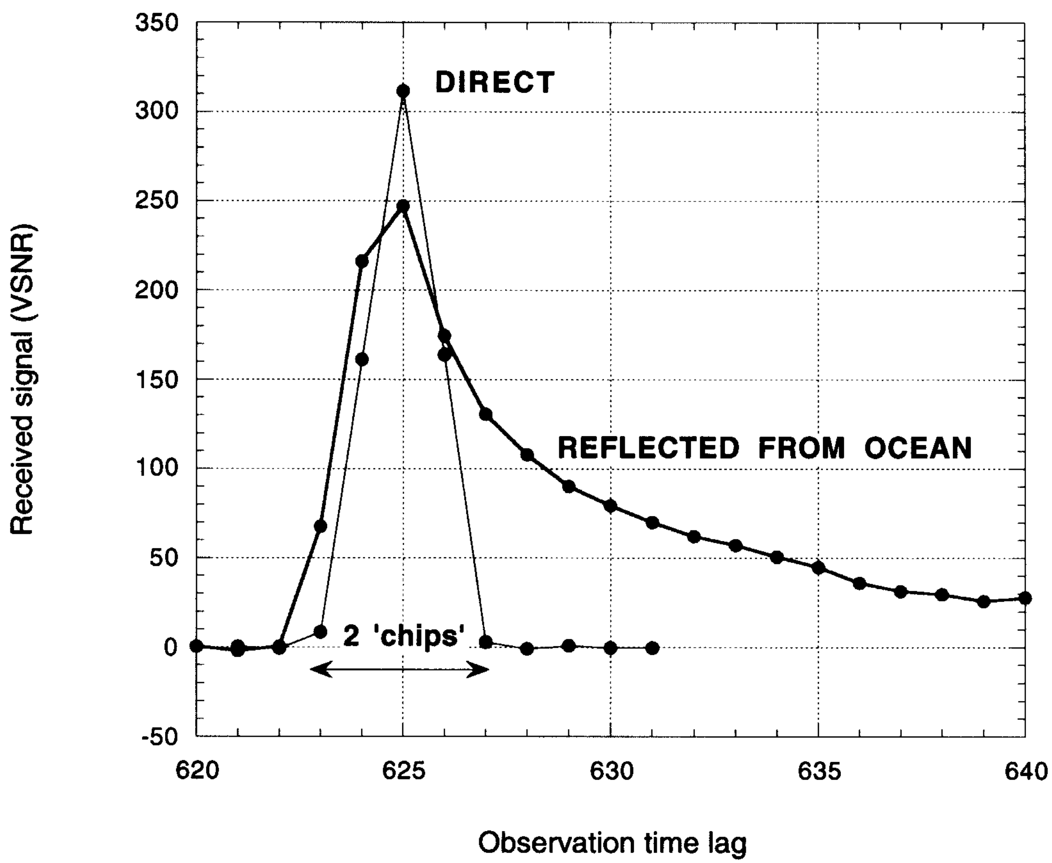
- **Sea Surface Heights Are Obtained Not Only Along The Altimetry Tracks But At Many Points In Between, Allowing To Monitor Phenomena With Small Spatial Scales**

THESE TWO FEATURES WILL ALLOW ONE TO TRACK FAST-MOVING WAVES AND MESOSCALE EDDIES!

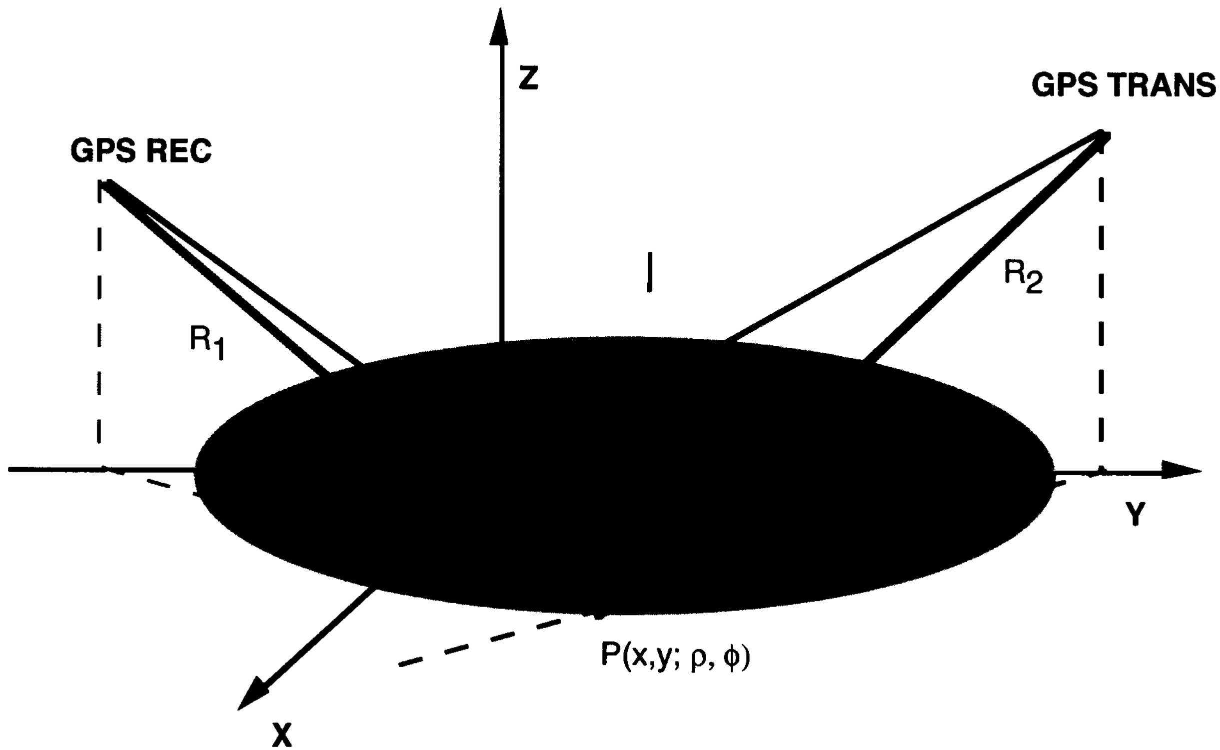
THE 'GPS REFLECTION' MEASUREMENT



DIRECT AND REFLECTED SIGNAL CHARACTERISTICS

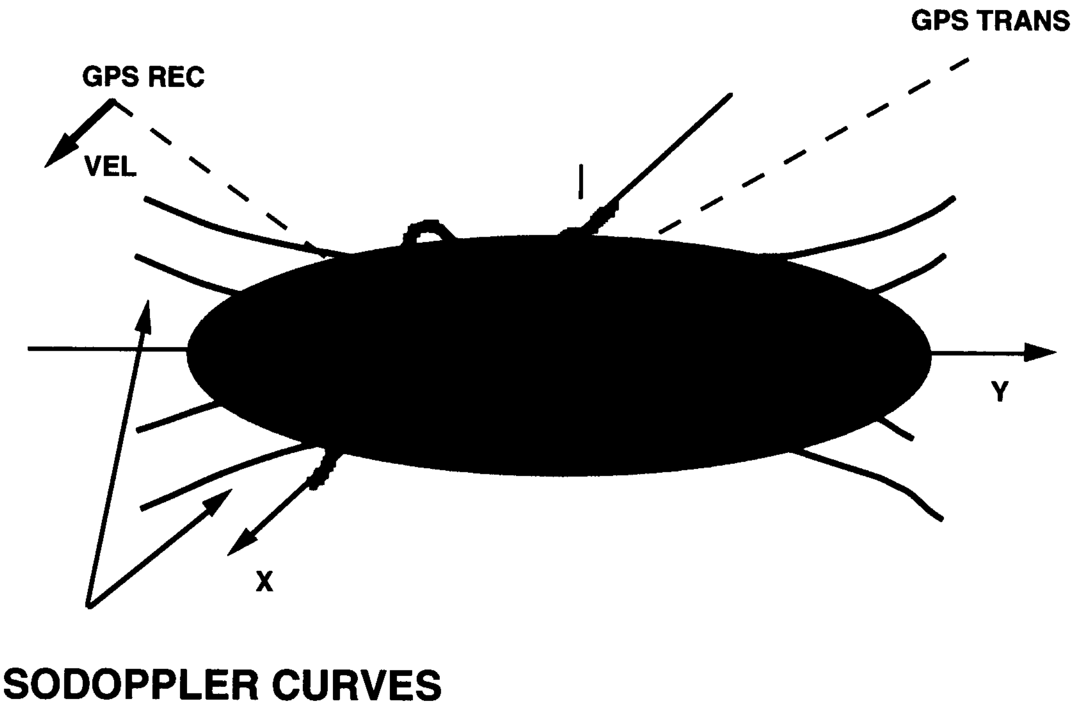


ORIGIN OF THE REFLECTED SIGNAL (1)



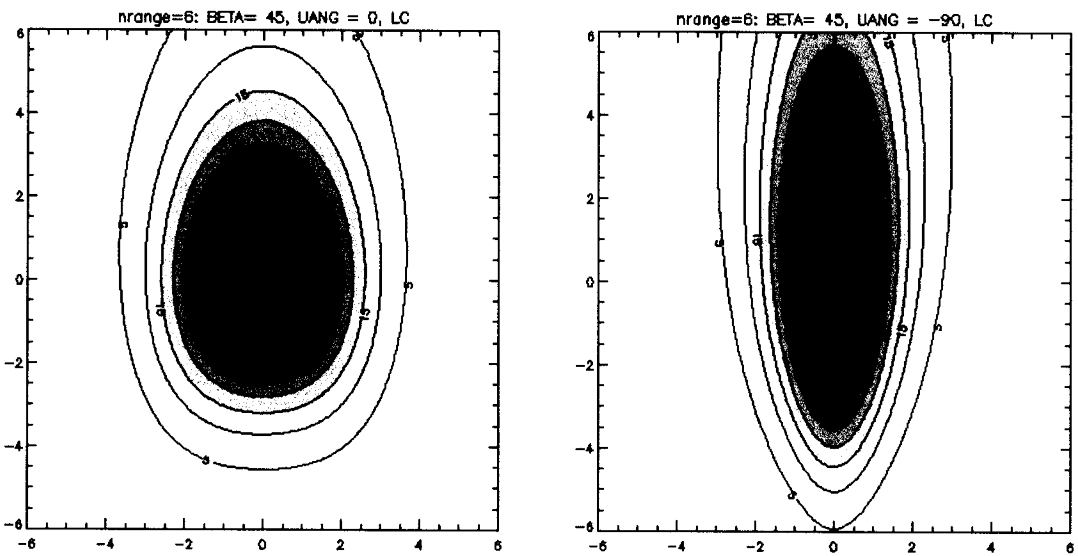
Contributions From Each Annulus Arrive At The Same Time, Sampling Ocean Surface In Preferential Directions

ORIGIN OF THE REFLECTED SIGNAL (2)



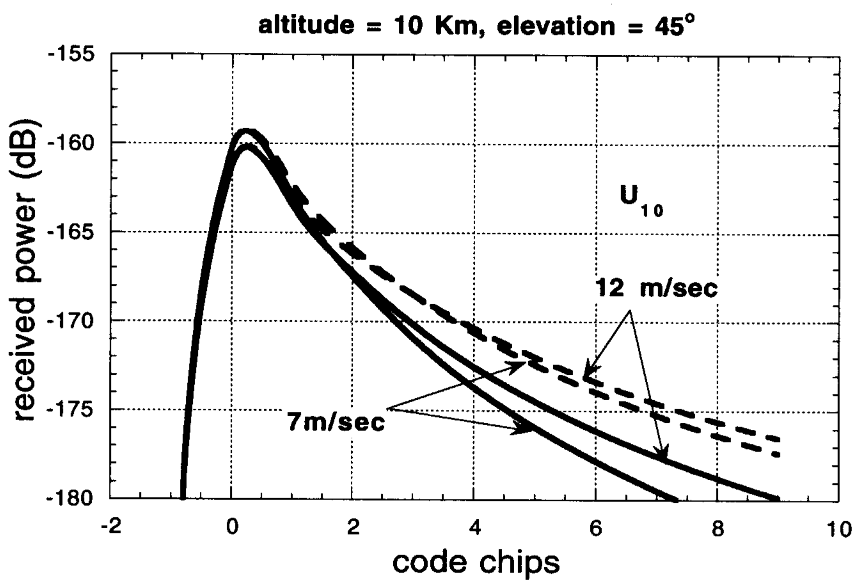
Platform Motion Introduces Further Directional Selectivity

SURFACE ROUGHNESS EFFECTS

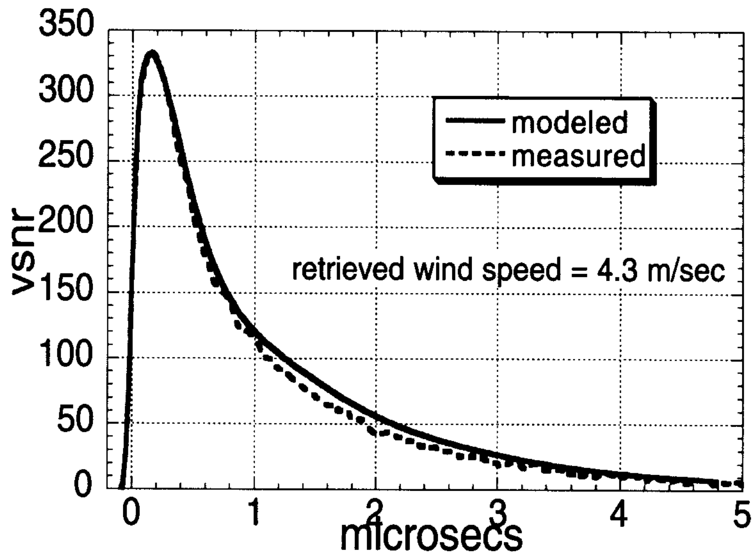


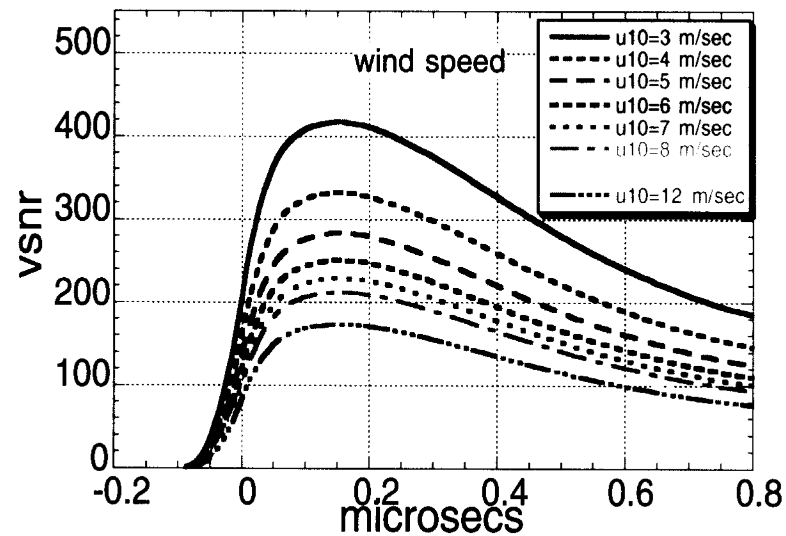
Spatial Distribution of Bistatic Scattered Field for Wind Driven Ocean (U_{10} = 4 m/sec)
Left – Wind Along Horizontal Axis
Right – Wind Along Vertical Axis

ROUGH SURFACE EFFECTS



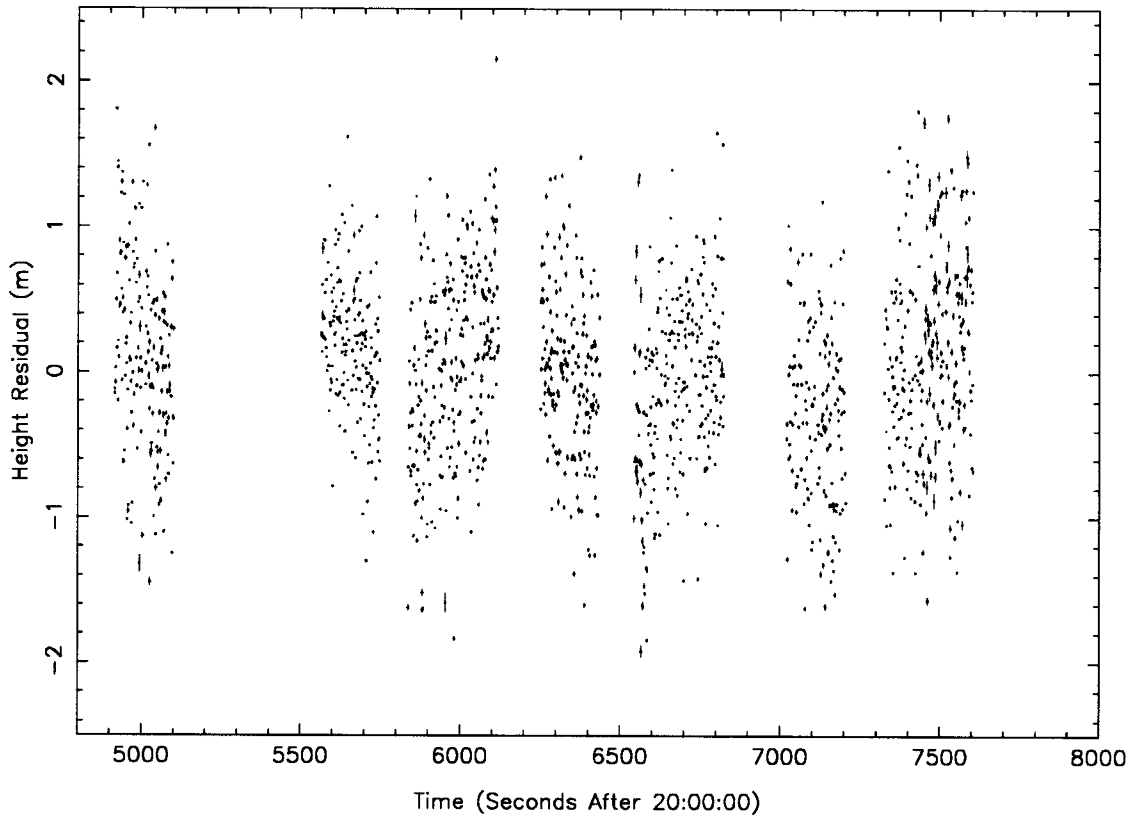
GPS ALTIMETRY FROM SPACE





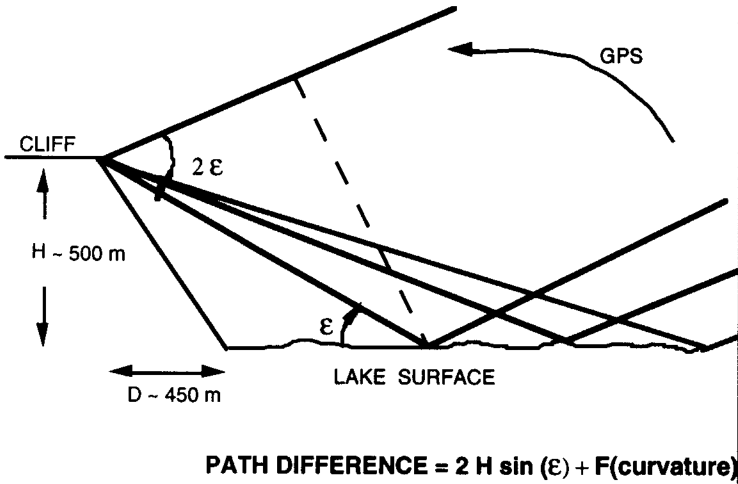
GPS Signal Reflection Collected Fortuitously From Sir-C Radar Flying On Space Shuttle In 1994

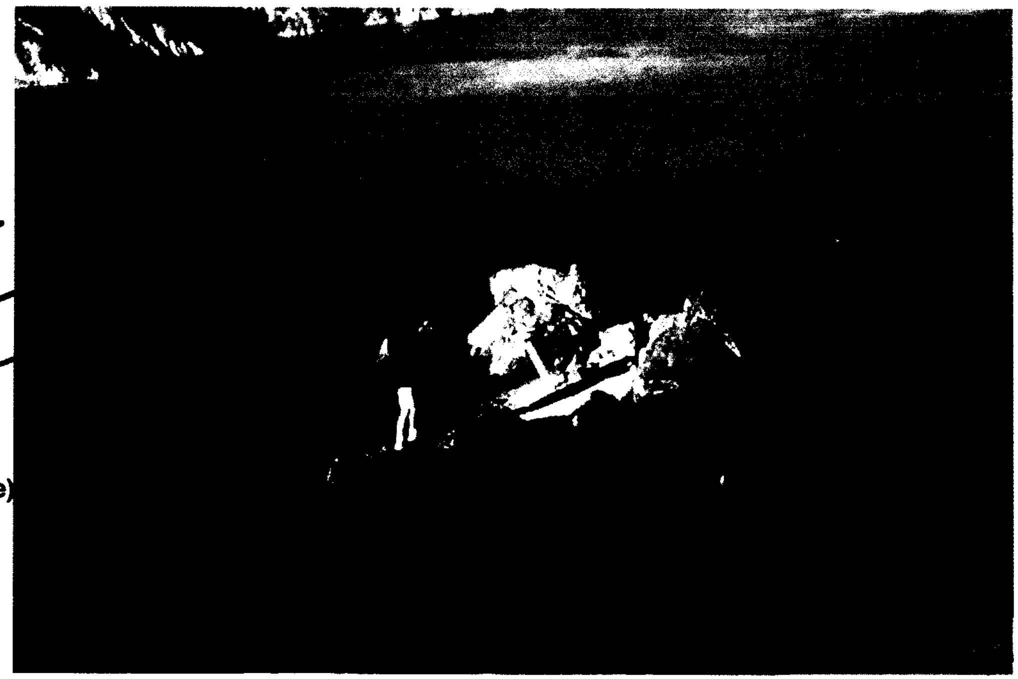
GPS ALTIMETRY FROM AIRPLANE



AVERAGE HEIGHT RMS = 5.5 cm in 1 sec

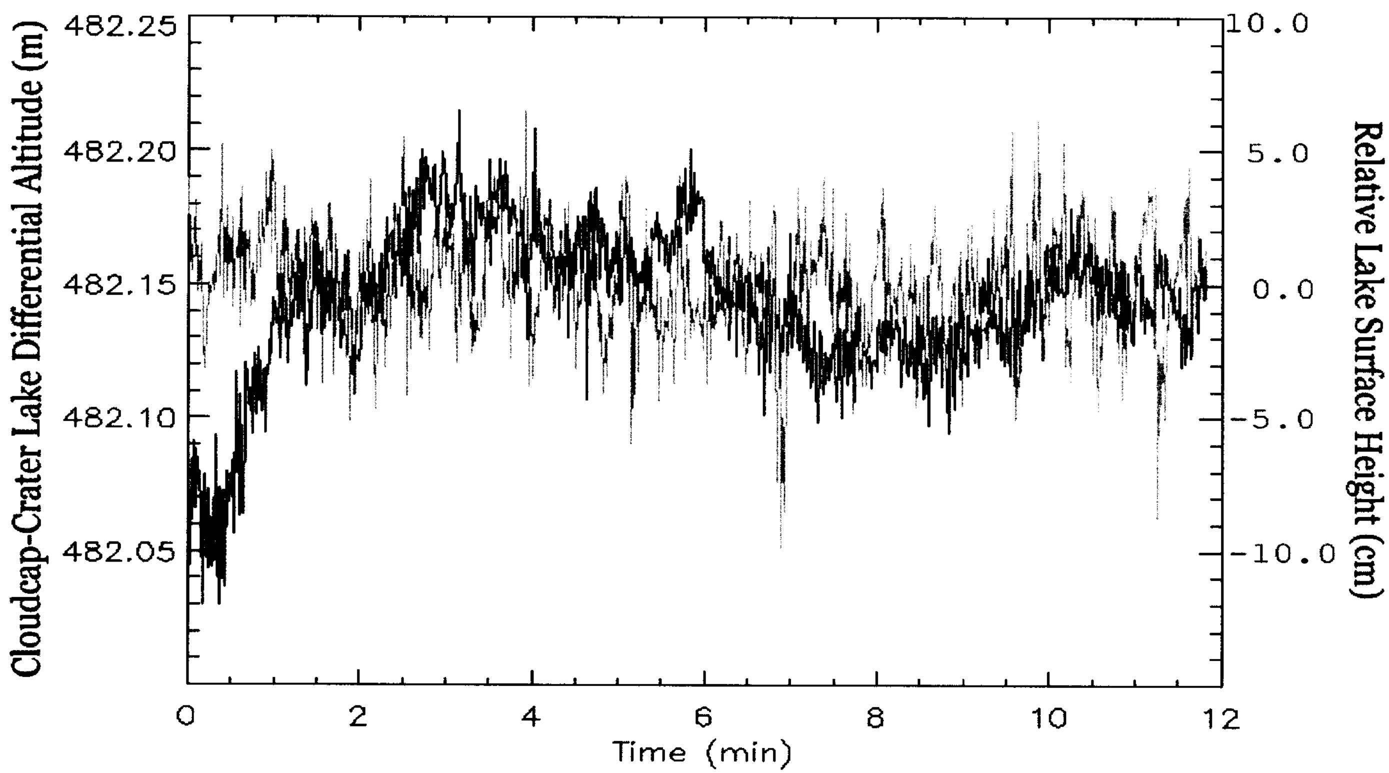
GPS ALTIMETRY AT LAKESIDE





Fixed GPS Receiver
Low Elevation Reflection Geometry

GPS ALTIMETRY FROM FIXED RECEIVER AT LAKESIDE



ESTIMATING HEIGHT FROM PHASE, RMS ERROR = 2 cm/sec (C/A CODE)

DATA ACQUISITION SYSTEM

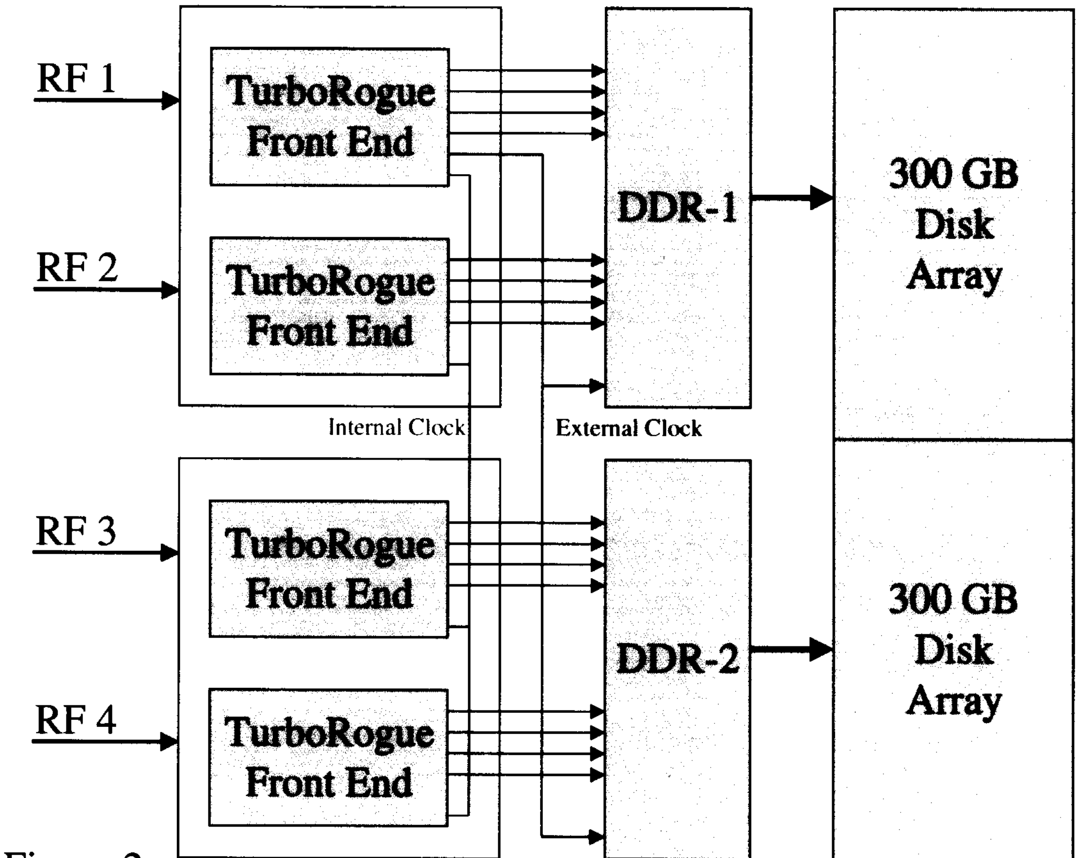


Figure 2.

RECEIVER DEVELOPMENTS

Developed Software Receiver System With A 50 Nsec Time Resolution, Unlimited Number Of Delay Points, Up To 8 KHz Output Bandwidth; Can Coherently Integrate By Any Multiple Of 125 μsec

- Maximum Data Processing Flexibility, New Receiver Technology Simulator, Feed-back on Receiver Design

Can Perform The Internal Cross-Correlations With Different Frequency Offsets, Mapping The Reflected Signal's Doppler Contributions

Aided Open-Loop Acquisition For SAC-C And CHAMP Black Jack Receivers And Antenna Digital Beam Steering Are Being Developed (Uses Nominal Models For Reflection, Direct Signal For Clock Error Correction And Outputs Correlation Products At High Rate)

PRELIMINARY CONCLUSIONS

Demonstrated Feasibility of GPS-Based Altimetry :The Basic Features Of The GPS-Based Altimetry Measurement Have Been Investigated And Its Potential Suitability For Eddy Monitoring Has Been Shown

Results Include:

The Only Ocean Altimetry Measurement Made With A Moving Platform

Retrieved sea surface height with 5 cm precision from airplane (5 km spatial resolution) Suitable for eddy monitoring

The Most Precise GPS Lake Altimetry Measurement From A Fixed Site Receiver

Retrieved lake surface height with 2 cm precision

Acquired first reflection data from space (SAC-C)

FUTURE STEPS

REQUIREMENTS:

- **High Gain, Multi-Beam Antenna Systems (30 dB In Space)**
- **Long Incoherent Averages And Combinations Of Colocated Measurements Over Several Days**

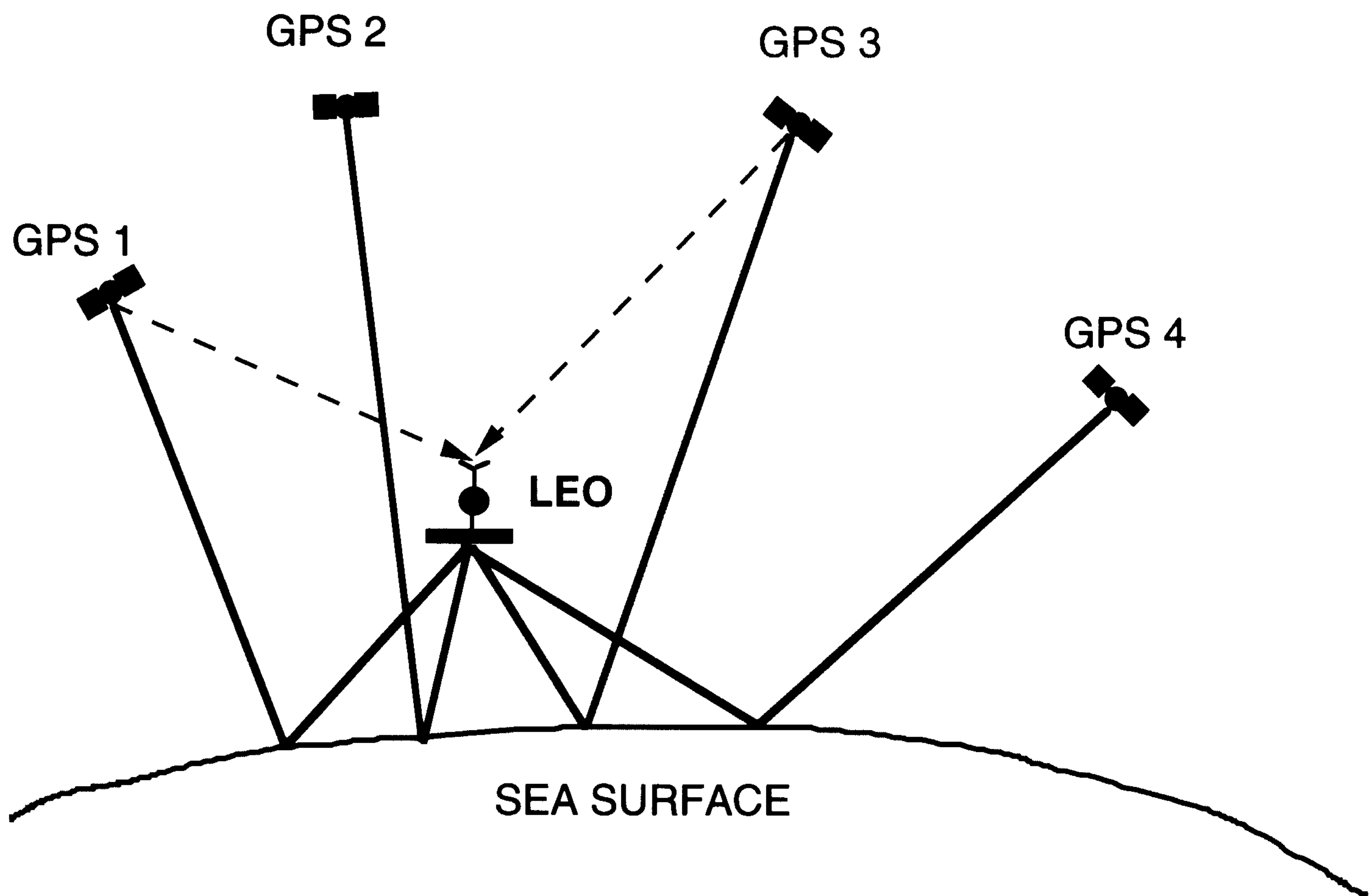
<u>CONSTELLATION OF SATELLITES CARRYING GPS RECEIVERS</u>

FOOTPRINT (km^2):	**AIRPLANE (10 km)**	**6 x 4 @ 45°**
	SPACE (400 km)	**32 x 24 @ 45°**

ACCURACY FUNDAMENTALLY LIMITED BY:

1. **Available GPS Signal Level (-157 dBw For C/A)**
2. **Ocean Bistatic Scattering At L-Band(14 dB $< \sigma_0 <$ 18 dB, Depending On Wind Speed)**
3. **Ocean Coherence Time At L-Band(1 Msec $<$ T $<$ 10 Msec)**

MULTIBEAM STEERABLE ARRAY CONCEPT



TECHNOLOGY DEVELOPMENT SALIENT STEPS

NEXT STEPS INVOLVE DEVELOPMENT OF HIGHLY PARALLEL MULTI FRONT-END GPS RECEIVER AND A MULTIBEAM HIGH GAIN ARRAY FOR SIMULTANEOUS ACQUISITION AND PROCESSING OF REFLECTIONS

1. **Develop A State-Of-The Art GPS Multiple Front-End Receiver Capable Of On-Board Processing Of Reflections, Suitable For Rapid Transition To Space Deployment**

2. **Integrate The Receiver, With A High Gain Antenna Array, And Fly It On Airplanes At A Variety Of Altitudes To Collect Abundant Measurements**

3. **Establish The Intrinsic GPS-Reflections Measurement Accuracy For A Spaced-Based Deployment**

EDDY-RESOLVING CONSTELLATION CONCEPT

1 RECEIVING SATELLITE

	2 DAYS	10 DAYS
50 km x 50 km	18 cm	8 cm

2 RECEIVING SATELLITES

	2 DAYS	10 DAYS
50 km x 50 km	13 cm	6 cm

8 RECEIVING SATELLITES

	2 DAYS	10 DAYS
25 km x 25 km	13 cm	6 cm

~1 DAILY 4-SEC MEASUREMENT IN EVERY 50 km x 50 km CELL PER RECEIVING SATELLITE; SATELLITE COVERAGE UP TO +/- 65° LAT; 10 GPS SATELLITES VISIBLE AT ANY GIVEN TIME

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